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***published in***
Review of Urban & Regional Development Studies
1999

***DOI (link to publisher)***
10.1111/1467-940X.00004

***document version***
Publisher's PDF, also known as Version of record



***citation for published version (APA)***
Buurman, J. J. G., & Rietveld, P. (1999). Transport infrastructure and industrial location: the case of Thailand. *Review of Urban & Regional Development Studies*, *11*, 45-62. https://doi.org/10.1111/1467-940X.00004

RURDS Vol. 11, No. 1, March 1999

# TRANSPORT INFRASTRUCTURE AND INDUSTRIAL LOCATION: THE CASE OF THAILAND

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This paper addresses the impact of transport infrastructure projects of manufacturing employment in Thai regions. After a theoretical review we consider the impact of various transport modes: road, rail and ports. We find that roads and ports have a positive impact on industrial location, although the size of the impact is modest. Labor appears to be a more important location factor in Thailand. For the analysis of the data, geographical information systems (GIS) appear to be a quite useful tool.

## 1. Introduction

Transport infrastructure is often considered as a main factor determining regional development. Governments of many—especially peripheral—regions favor expanding infrastructure networks to improve their access with the rest of the world; they expect beneficial effects for economic activity in their regions. However, the theoretical literature on the subject is much less definite on this issue (Krugman, 1991, Vickerman, 1991, OECD, 1995, and Bröcker, 1996). In many countries a clear gap exists between the views of policymakers and analysts.

This paper is an empirical analysis of the effects of infrastructure improvements in Thailand on the manufacturing sector in the regions concerned. We analyze the extent to which proximity of roads, railways and ports have an impact on industrial location. In Section 2 we give a review of the literature, followed by a description in Section 3 of regional development patterns in Thailand. Empirical results are surveyed in Section 4. Section 5 offers concluding remarks.

## 2. Infrastructure and Regional Development: A Review

As indicated in Table 1, transport infrastructure investments have both temporary and non-temporary effects on the economy. A major temporary effect concerns the stimulation of employment and income during the construction phase via the demand side.

This effect can be studied by input-output analysis. More advanced approaches would entail the use of equilibrium models where feedback from various markets is taken into account. For example, a tax increase or an increase in interest rates due to government borrowing on the capital market would have a negative impact on consumption or investment, which would counter the initial demand stimulating the effect of government spending. Such crowding-out effects are often ignored in regional or urban studies where the infrastructure project is considered "small" compared with the size of the national economy. However, if local projects are financed by local financial resources (local


Published by Blackwell Publishers, 108 Cowley Road, Oxford, OX4 1JF, UK and 350 Main Street, Malden, MA 02148, USA.

**Table 1. Temporary and Non-temporary Effects of Transport Infrastructure Investments**

| | Demand Side | Supply Side |
|---|---|---|
| Temporary | construction effects; crowding out | - |
| Permanent | operations and maintenance | effects on productivity and location of factors |

taxes), one should take into account the impacts of these taxes on investment behavior of firms in the area concerned.

Another demand related effect of infrastructure occurs in the field of operations and maintenance; this effect is permanent. Although maintenance does not strike the imagination of the general public as much as new infrastructure projects, it is nevertheless an important activity (OECD, 1986), with high rates of return on investment.

In this paper we will pay special attention to permanent effects on the supply side. Figure 1 shows a number of possible effects which are relevant for an economic analysis of transport infrastructure investments: generalized transport costs, GDP, employment, environment, welfare and equity.

Transport infrastructure investments lead to changes in generalized transport costs via shorter distances or higher speeds, which give rise to reductions in fuel, capital and labor costs. Such changes will impact the transport system in the form of mode choice, choice of time of day (in the case of congested networks) and the generation and attraction of trips per zone.

The reduction in generalized transport costs in combination with the changes in transport flows of firms lead to an increase in productivity in the firms concerned. This increase will manifest itself in the form of a change in value added, which will in turn lead to a growth of gross domestic product (GDP) in the region or country concerned.

Effects on employment of infrastructure investment take place among others via substitution and complementarity relationships between labor, private capital and infrastructure. They also occur via differences in growth rates of economies in regions due to the differences in advantages they receive from changes in infrastructure networks.

In the figure we have sketched various effects of infrastructure on the economy. In the following discussion it will be shown that infrastructure investments are not always a panacea for employment growth in regions or countries. We will discuss subsequently transport infrastructure as a production factor, transport infrastructure and interregional/international trade.

## 2.1 Transport Infrastructure as a Production Factor

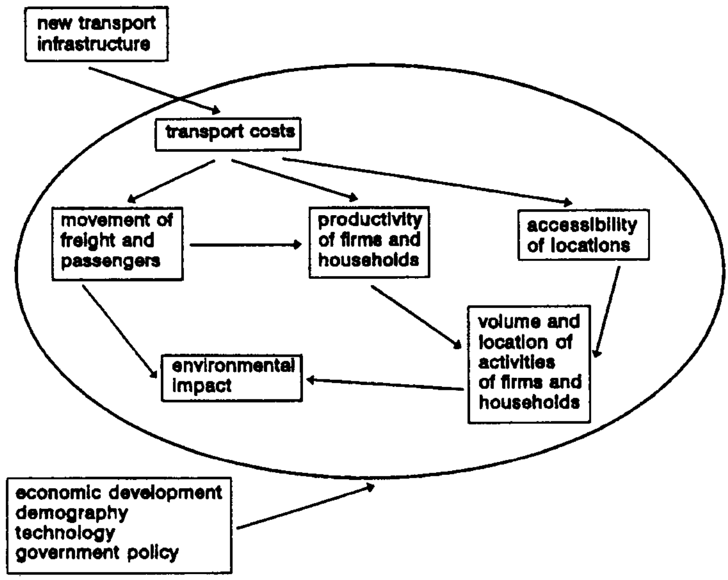
Transport infrastructure can be considered as a stock of a certain type of capital available to a region or a country (Aschauer, 1989). A general formulation of a production function for sector *i* in region *r*, with various types of infrastructure is:

$$Q_{ir} = f_{ir}\,(L_{ir}, K_{ir}; IA_r, \ldots, IN_r) \qquad (1),$$

where:

$Q_{ir}$ is value added in sector *i*, region *r*
$L_{ir}$ is employment in sector *i*, region *r*
$K_{ir}$ is private capital in sector *i*, region *r*
$IA_r, \ldots, IN_r$ is infrastructure of various types in region *r*

**Figure 1. Relationships between Transport Infrastructure and Spatial Development**




Among the types of infrastructure distinguished are: transportation, communication, energy supply, water supply, education, etc. As far as transport infrastructure is concerned, its network properties are usually not taken into account in the production function approach. An approach one can follow is to distinguish various types of transport infrastructure according to their spatial range: intraregional, interregional and possibly international.

A related aspect of infrastructure is that its impact may transcend the boundaries of regions. A certain region may benefit from a university or airport, even though these facilities are not located in the region itself. This problem of spatial spillovers may be solved by using the concept of accessibility of certain types of infrastructure in the production function (see Johansson, 1992).

What are the services offered by transport infrastructure that increase productivity? First, the improvement of transport infrastructure enables a reduction of the costs for the collection of inputs and the distribution of outputs. Second, improvement of transport infrastructure leads to better functioning of labor markets, which in turn may lead to higher labor productivities. Also, productivity of private capital may increase.

Production functions of type (1) can be used to derive demand functions for labor and private capital. With respect to labor demand, two effects can be distinguished. First, an increase in the availability of infrastructure leads to a shift in the optimum allocation of labor $L$ and private capital $K$ at a given level of production. This shift may be such that the total level of both $L$ and $K$ needed to produce the same volume of output is decreased (Figure 2a). But it may also occur that demand for $L$ increases and demand for $K$ decreases (Figure 2b) or vice versa. In all cases, the total costs of private production factors will decrease. In other words, the direction of the first effect of infrastructure improvement on labor demand is not certain.

A second effect is that due to the decrease in the costs of production, output can be expanded. This will, under the usual assumptions, lead to an increase in the demand for private production factors. Thus, we arrive at the conclusion that when output remains constant, improvement of infrastructure may lead to a decrease in labor demand. On the other hand, a decrease in production costs can induce a higher output, which has a positive effect on employment. These results hold true when we ignore the impacts of transport infrastructure on interregional or international trade. A discussion of the latter is given in the next section.

## 2.2 Transport Infrastructure and Interregional/international Trade

The standard model of interregional trade is illustrated in Figure 3. Export takes place from region 1 to region 2 when transportation cost is less than the difference in equilibrium price for a certain good in both regions. Compared with the situation without trade, an additional surplus is created consisting of areas A (accruing to producers in region 1) and B (accruing to consumers in region 2). Thus, both regions benefit from trade according to the model.

Improvement of infrastructure leads to a decrease in transportation costs and hence to an increase in transportation volumes. The equilibrium price in region 1 will increase; the price in region 2 will decrease. Thus, in region 2, consumers benefit from the improvement in infrastructure, whereas producers are negatively affected. In region 1 it is the other way around. In employment terms, region 1 benefits; region 2 is hurt by the improvement of transportation infrastructure.

The model sketched is a partial equilibrium model. It deals with the market for only one good. General equilibrium models are more adequate to analyze the effects of changes in infrastructure, but are of course more complex. Figure 4 (taken in adapted form from Pluym and Roosma, 1984) presents some of the main effects when more than one sector is considered. In this case the net effects are difficult to predict.

Labor market flexibility is important to overcome potential friction in the labor market, which may be the consequence of changes in transport costs. With flexibility, workers in sector A who lose their job due to changes in transport costs may find work in the expanding sector B. Without such flexibility one might have a combination of high total unemployment in one sector and a high level of vacancies in the other. Thus, a flexible labor market is important to realize potential employment gains in regions affected by transport infrastructure investment.

An important aspect of the above is that improved transport infrastructure enables firms to make use of economies of scale in production. This leads to specialization tendencies of regional economies with positive impacts on certain factors and negative impacts on others.

In terms of the types of infrastructure considered, it can be noted that in the productivity approach the intraregional aspects of the services of infrastructure are emphasized, whereas in the trade approach the interregional aspects come to the fore.

## 2.3 Temporal Aspects

Since infrastructure has a long lifetime, it may have long lasting impacts on the space economy. In some cases, the impacts may already be visible before the infrastructure has been completed: firms may anticipate the completion of infrastructure in their locational choices. Anticipation may have advantages in terms of lower land prices.

**Figure 2. Allocation of Labor and Capital Before and After Improvement of Infrastructure**

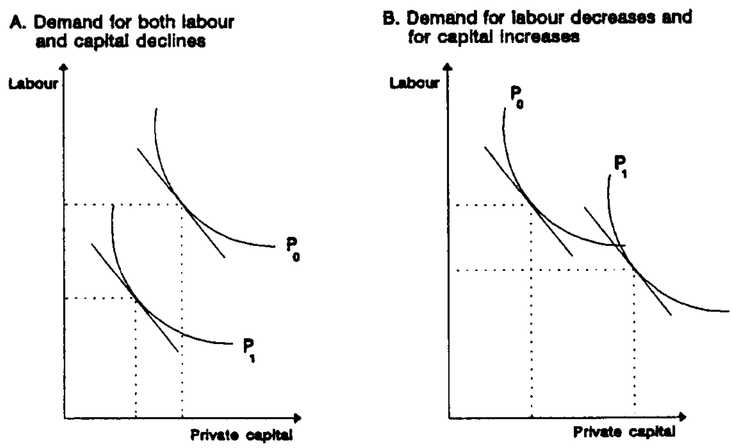



**Figure 3. Supply and Demand in Two Regions**

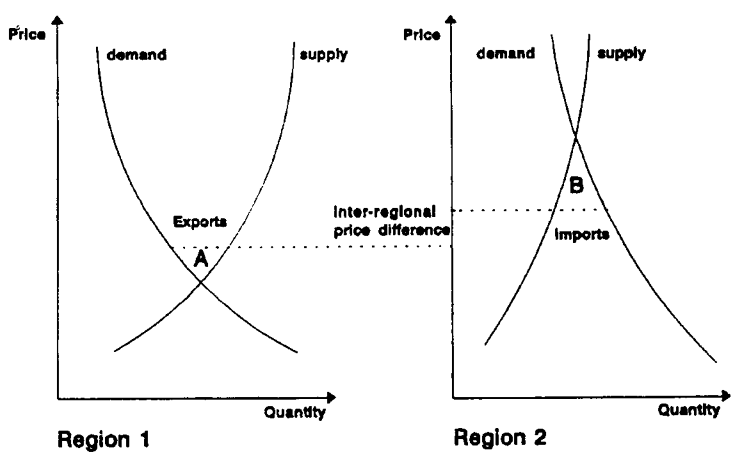
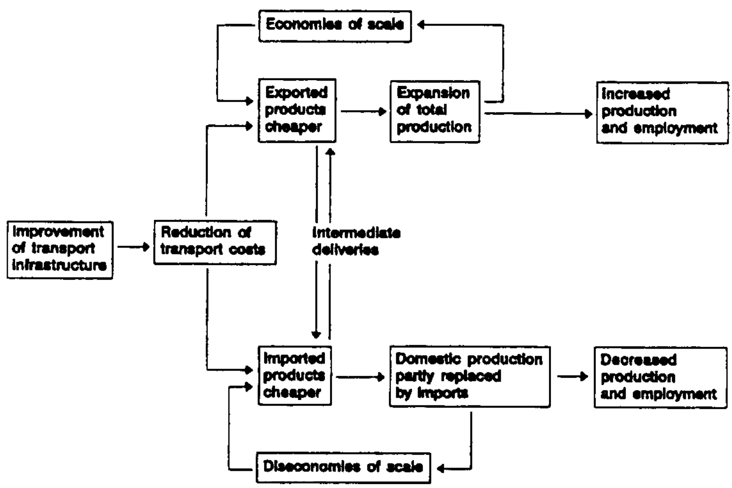


**Figure 4. Impact of Improvement of Transport Infrastructure on Location of Economic Activity**




The obvious risk is that the infrastructure will not be completed as planned. Thus the reliability of the public sector in the planning of major infrastructure projects is a major determinant of the extent to which relocation effects can already be observed before the realization of the project.

The above sections are meant to be a very short review of the relevant literature, and have not touched several important issues, e.g., the implications transport infrastructure improvements may have for the logistical organization of firms including the introduction of just-in-time delivery of goods to and from factories (see McKinnon, 1996). A more complete review can be found in Rietveld and Bruinsma (1998).

## 2.4 Causality

An important theme in infrastructure analysis is the issue of causality. For example, in his review of studies on the contribution of infrastructure to productivity, Gramlich (1994) indicates that almost all empirical studies of equation (1) ignore the possibility that the relationship between infrastructure and production is based on the reversed relationship: rich regions have more resources to invest in infrastructure than poor regions, or in a temporal setting: during a period of high economic growth there are more resources for such investments than in periods of low growth.

The causality issue may also be important for the analysis of employment impacts of infrastructure. Firms locate where the conditions in terms of infrastructure, agglomeration incentives, labor supply, and investment incentives are favorable. On the other hand, labor will be attracted to regions where the manufacturing sector is developing favorably. Thus, there is a two-sided relationship between the two. A further discussion of these points can be found in Rietveld and Bruinsma (1998). They indicate that when dynamic data are available, statistical methods can be used to address the causality problem, but that the results are often rather inconclusive.

## 3. Regional Development in Thailand: the Eastern Seaboard

The spatial distribution of Thailand, with its population of about 60 million inhabitants, is dominated by the Bangkok Metropolitan Region (BMR), where about one sixth of the total population is living. The second biggest metropolitan area in the country, Nakhon Ratchasima, is about eight times smaller than the BMR. Economic development outside the BMR has focused on agriculture (Thailand being a main exporter of agricultural products) and tourism. From 1986 until 1990 the Thai economy experienced a boom, with annual growth rates of 10%. Since this period foreign investments in manufacturing have also been extensive, but have been strongly biased towards the BMR (see Phongpaichit and Baker, 1996). Given the high level of congestion in Bangkok and the regional disparities, the government of Thailand has developed programs for economic development in other regions. One of the regions selected for development of manufacturing is the Eastern Seaboard (ESB). It is to the eastern seaboard that the present paper is devoted.

The ESB is located in Southeast Thailand, bordered by the BMR, the Gulf of Thailand, Cambodia and the poor Northeastern region (see Map 1). It has a share of some 10% of the total area and population of the country. The largest city is Chonburi (about 220.000 inhabitants). There are several other urban complexes, e.g. Pattaya, Rayong and Map Ta Put, with more than 200,000 people. The ESB is, after the BMR, the most industrialized region in Thailand, with about 7,000 factories (figures from 1996). This is partly due to the Eastern Seaboard Development Project (ESDP), which started in 1981 and is currently in its second phase.

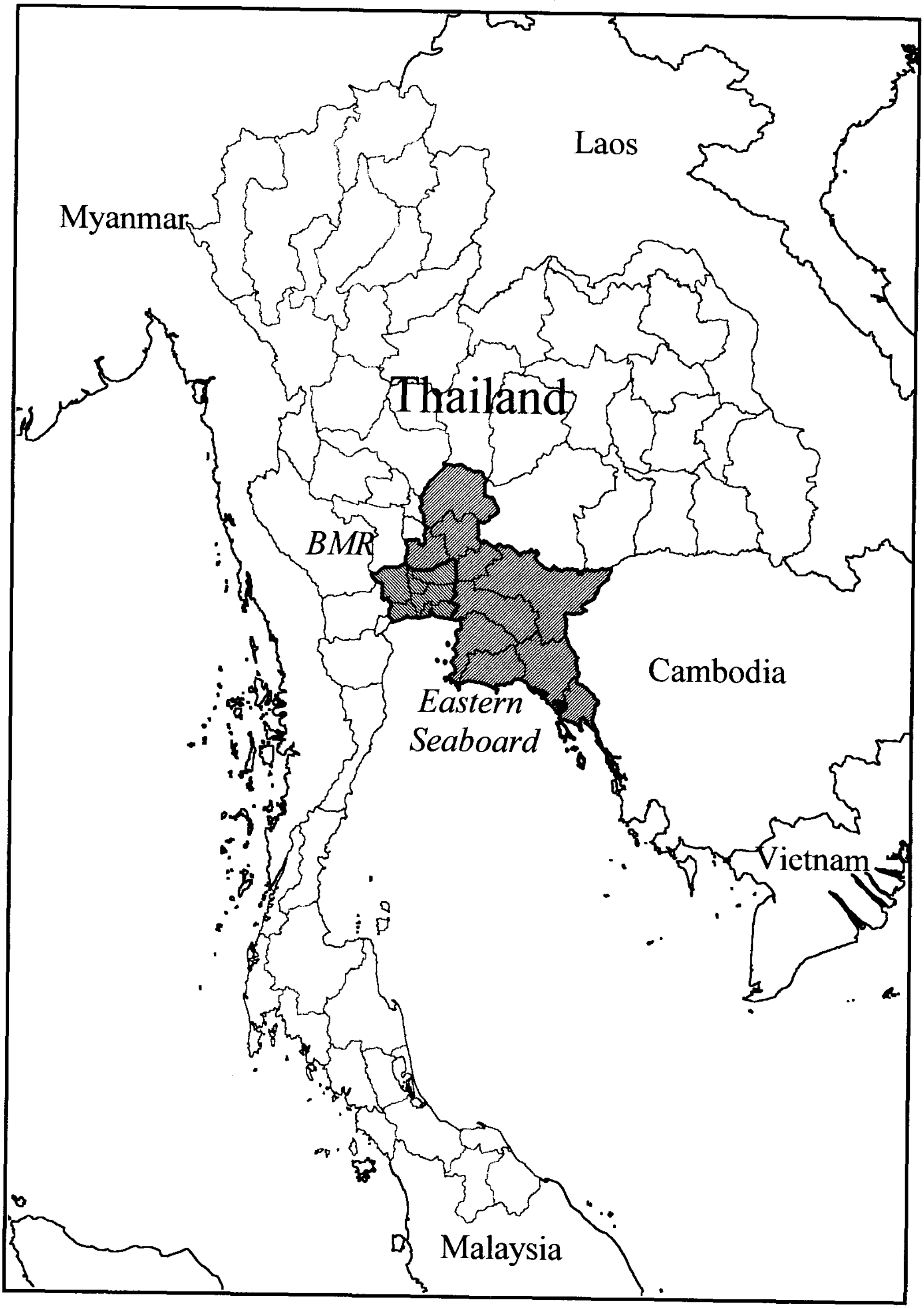
Within the Eastern Seaboard exist great disparities in regional development. The economic development strongly concentrated on the provinces close to Bangkok. Indeed, the first phase of the ESDP only comprised three of the eleven provinces, all of them close to the BMR. The fact that the ESB was chosen to stimulate development was due to its strengths: a good location with access to Bangkok, the sea and Indochina, plenty of undeveloped land available and camparatively good infrastructure. At the time this research took place (early 1997), one of the ESB's main weaknesses was an inadequacy of manpower at all levels of qualifications and skills. Companies experienced particular difficulty in finding people with specialized (technical) training, though unskilled labor was also not abundant. Other problems in the ESB are competition among industries over the utilization of water, agriculture and urban development, degradation of coastal areas and lack of infrastructure in remote areas.

### 3.1 Infrastructure in the Eastern Seaboard Region

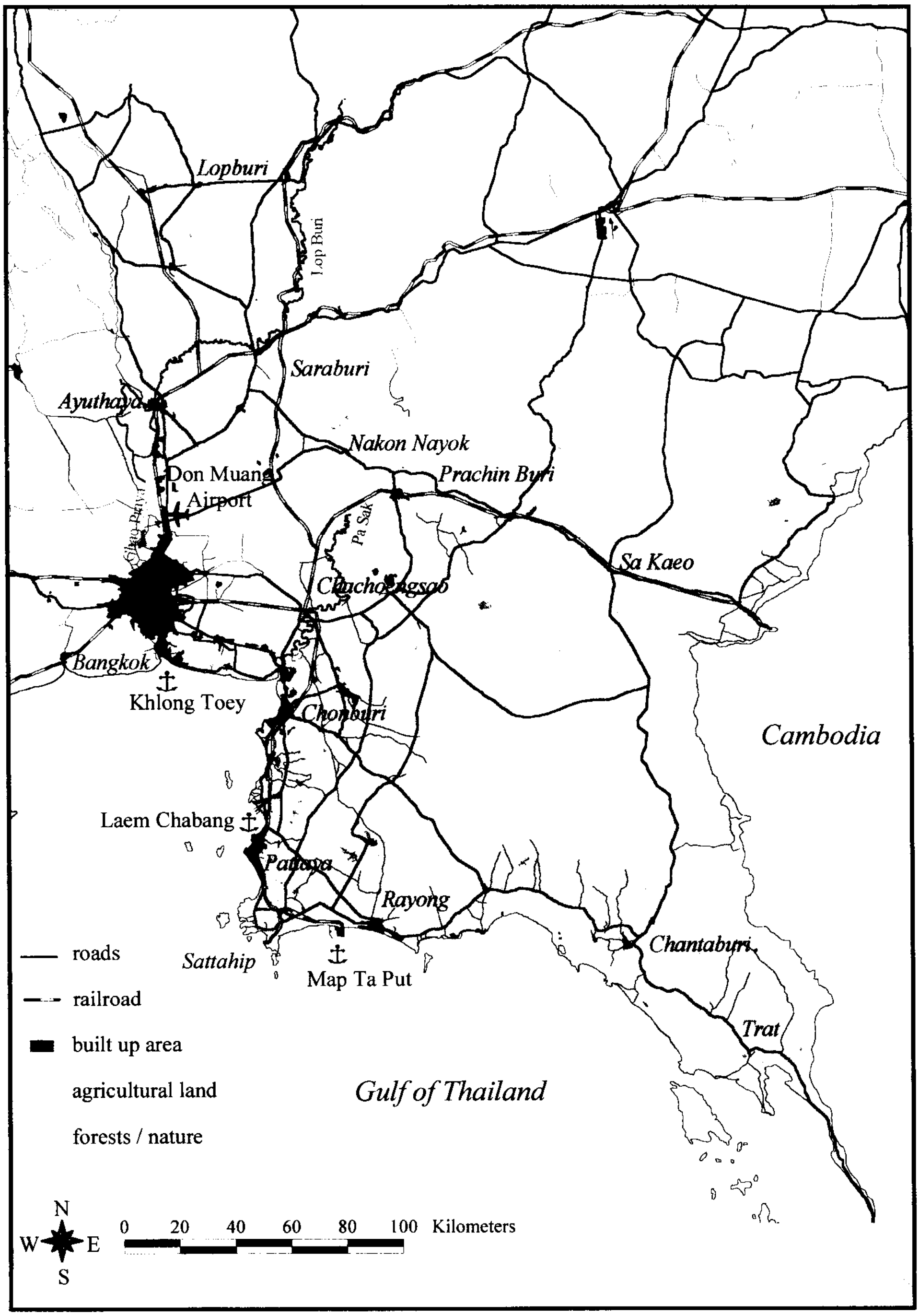
The road system has been expanded rapidly during the past decade in the ESB region. In 1994 the density was about 0.14 km per km$^2$, compared to a ratio of 0.10 for the country as a whole. Road densities tend to be higher in those parts of the ESB region that are closer to the BMR (Map 2).

Railways, neglected since 1945, have more recently seen construction of some new lines. They provide connections between the seaports in the ESB region and the hinterland. The ports concerned are Laem Chabang and Map Ta Put, which form the core of the ESB development project. In addition to

**Map 1. Location of the Study Area**



**Map 2. Infrastructure and Land Use in the Eastern Seaboard Area**



these, the Khong Toey port near Bangkok is used for transport from/to the ESB region.

The region does not have an international airport. Air transport takes place via Don Muang airport, located north of Bangkok. One of the priorities of the government's infrastructure policies is not just access to infrastructure, but also level of service provided, which is an important determinant of the reliability of transport chains, especially in a multimodal context.

## 4. Statistical Analysis of Infrastructure and Industrial Development in Southeast Thailand

Spatial data on industrial development in Thailand are rather weak. At the provincial level, data on industrial production are available, but without sufficient detail to study the impact of infrastructure. We make use of data from the Ministry of Industry (MoI), the Industrial Estates Authority (IEAT) and the Board of Investment (BoI). The MoI and the IEAT register respectively factories outside and inside industrial estates. A BoI application is required for an enterprise to obtain tax and other privileges. Data are available at the level of amphoe (region) or tambon (community), of which there are 100 and 905, respectively, in the study region. The disadvantage of the data is that we only know the number of workers at the time of registration, which is usually at establishment, relocation or if BoI assistance is asked, and thus may be a poor proxy of the actual number of workers when the firm develops further.

### 4.1 Analysis of Industrial Location at Amphoe Level

The following variables have been used to analyze the location patterns of industrial firms a the level of the amphoe:

Accessibility variables:

1. Distance to markets. For many companies this is the distance to Bangkok, the main market. Some companies produce for the local market; the size of most of such cities, however, is small compared to Bangkok. Distribution to other parts of the country is usually via ports or Bangkok. For companies that do not produce for the Thai market, the distance to a seaport or an airport is important.
2. Distance to seaports. Companies in the ESB use three international deep seaports: Khlong Toey near Bangkok, Laem Chabang and Map Ta Put.
3. Distance to airports. The only significant airport for cargo in Thailand is Don Muang Airport, north of Bangkok.
4. Accessibility by road. Road transport is by far the major transport mode in Thailand. In contrast to the other explanatory variables above, it concerns network infrastructure. Roads are used to transport inputs to the factory and outputs to markets and ports. Additionally, roads are used for the transportation of employees and visitors of the company.
5. Accessibility by railroad. This is another type of network infrastructure. Companies use rail transportation to transport their goods to and from Bangkok or one of the ports. Passenger transport by railroads is only of importance when it concerns employee commuting.

Other variables:

1. BoI incentives. For the location decision of companies this should be a significant variable. The BoI distinguishes two investment promotion zones in the Eastern Seaboard. In the five provinces next to the BMR, except for the port areas, the incentives comprise less than in the other six provinces. However, the incentives system with different zones has been in operation since 1993. The number of established factories since 1993 is, on the

other hand, 26% of the total number of factories established since 1969.

2. Availability of employees. This should be an important variable, but there exist no good data for it. For the regression analysis number of inhabitants will be used as a substitute.

Using these variables, the following linear regression model is proposed:

$$FACTDENS_r = \alpha_1 DISTROAD_r + \alpha_2 DISTRAIL_r + \alpha_3 DISTPORT_r + \alpha_4 DISTBANG_r + \alpha_5 BOI + \alpha_6 POPDENS_r + C \quad (2),$$

where:

| | |
|---|---|
| *FACTDENS* | is factory density: the number of factories per area unit (10 km$^2$) in an amphoe; |
| *DISTROAD* | is access by road, measured as the average distance in kilometers to a main road in an amphoe (representing interregional accessibility); |
| *DISTRAIL* | is access by railroad, measured as the average distance in travel time from an amphoe to a railway line (also representing interregional accessibility); |
| *DISTPORT* | is average distance in travel time from an amphoe to Laem Chabang or Map Ta Put (which lies nearest), measured as the crow flies; |
| *DISTBANG* | is distance to the main market, measured as the average distance in travel time from an amphoe to Bangkok; this variable also includes the distance to Don Muang airport and the distance to Khlong Toey deep sea port, because they are located close to Bangkok; |
| *BOI* | is a dummy variable with value 1 if the amphoe lies in zone III, value 0 if in zone II; |
| *POPDENS* | is population density, measured as the number of inhabitants per km$^2$; |
| $C$ | is a constant; |
| $r$ | is amphoe; and |
| $\alpha_1 \ldots \alpha_6$ | are parameters to be estimated. |

To remove the disturbing effect of the different sizes of the amphoes, the density of factories and population in an amphoe has been chosen as dependent variable. The accessibility variables (*DISTROAD*, *DISTRAIL*, *DISTPORT* and *DISTBANG*) have been calculated using a geographical information system (GIS). For the *DISTROAD* variable the distance from each 250x250-meter grid cell to the nearest main road has been calculated. The *DISTROAD* variable is the average value of all the grid cells that constitute an amphoe. For the other variables, the travel time by road has been calculated, starting from the amphoe's central city (or village). If an amphoe is not crossed by a main road, extra time to reach a main road has been added to the total travel time. The number of observations is 100 for all regression models at amphoe level.

We first consider the correlation coefficients of the variables used in equation (2), shown in Table 2. The factory density data relate to factories established between 1969 and 1995. The accessibility measures describe the situation in 1995; the BoI scheme has been effective since 1993; and the population density is based on 1993 data. The accessibility variables all have a negative correlation with *FACTDENS*. Thus a higher value of an accessibility indicator means a higher distance, which results in higher transport costs; the location is less favorable and has a lower density of factories. *FACTDENS* has a negative correlation with *BOI*. This dummy variable is 1 in zone III and 0 in zone II, which means that the factory density is lower in zone III. The high correlation of *BOI* with *DISTBANG* is inherent in the BoI incentive system, which

**Table 2. Correlation Coefficients for a Regression at Amphoe Level**

| | *FACTDENS* | *DISTROAD* | *DISTRAIL* | *DISTPORT* | *DISTBANG* | *BOI* | *POPDENS* |
|---|---|---|---|---|---|---|---|
| *FACTDENS* | 1.000 | | | | | | |
| *DISTROAD* | -0.360 | 1.000 | | | | | |
| *DISTRAIL* | -0.070 | 0.300 | 1.000 | | | | |
| *DISTPORT* | -0.264 | 0.309 | 0.021 | 1.000 | | | |
| *DISTBANG* | -0.213 | 0.248 | 0.825 | 0.311 | 1.000 | | |
| *BOI* | -0.206 | 0.062 | 0.471 | 0.172 | 0.732 | 1.000 | |
| *POPDENS* | 0.699 | -0.278 | -0.288 | -0.203 | -0.406 | -0.371 | 1.000 |

advocates location away from Bangkok. As this variable seems to explain the location of factories rather well, we will perform a sensitivity analysis of the regression to see what happens if we omit *BOI*.

The correlation coefficients of the independent variables among each other are in most cases moderate. Only the correlation between *BOI* and *DISTBANG*, which was discussed above, and the correlation between *DISTBANG* and *DISTRAIL* are quite high. The high correlation of *DISTBANG* and *DISTRAIL* results from the fact that the railroad network in Thailand has Bangkok as its center. Note that for *DISTRAIL* we find the smallest correlation (in absolute terms) with factory density compared to the other accessibility indicators. A multivariate analysis is needed to find out how the location factors influence factory location when they are considered jointly.

The results from the regression analysis at amphoe level are shown in Table 3. Regression A includes all variables discussed above; regression B is without *DISTRAIL*; and regression C is without *DISTRAIL* and without *BOI*. All models have a level of $R^2$ of about 55%. This is, however, largely due to the *POPDENS* variable. If this variable is omitted the $R^2$ decreases to about 21%.

The population density is clearly closely related to factory density. This can mean several things. First, a high population density means a high market potential. This is especially true for companies producing for the local market. Second, when locating in populated areas it is usually easier to find employees. Third, in populated areas agglomeration economies can exist. On the other hand, the link between population density and factory density can run the other way round. People can move to an area of employment opportunities, leading to increasing population density. Closer examination of factory and population settlement data in time, which were not available for the study, would be needed to elaborate on this.

If lagged data on population density (or even better, on labor force density) had been available, would this strongly affect results? One way to address this question is to investigate the correlation between population densities in various years. Since these data are lacking at the amphoe level we use provincial data to investigate. We find that correlations are high: between 1971 and 1995, almost perfectly covering our research period, it is 0.87. Although correlations at more detailed spatial levels are most probably smaller, one may expect that if population or labor force data had been used from the beginning of our research period one would still have found a substantial contribution in the regression analysis with industrial activities as the dependent variable. Further discussion of this is offered in Section 4.5.

**Table 3. Results of the Regression Analysis at Amphoe Level (n = 100)**
Note: a coefficient is in bold if significant at the 0.05% level following T-distribution.

| | A | | B | | C | |
|---|---|---|---|---|---|---|
| | coefficient | st. error | coefficient | st. error | coefficient | st. error |
| *DISTROAD* | **-0.993** | 0.360 | **-0.800** | 0.348 | **-0.762** | 0.341 |
| *DISTRAIL* | **0.213** | 0.117 | | | | |
| *DISTPORT* | -0.016 | 0.047 | -0.063 | 0.040 | -0.062 | 0.039 |
| *DISTBANG* | -0.064 | 0.103 | **0.094** | 0.055 | **0.072** | 0.040 |
| *BOI* | 1.269 | 7.064 | -3.730 | 6.586 | | |
| *POPDENS* | **0.129** | 0.015 | **0.130** | 0.015 | **0.132** | 0.015 |
| Constant | 8.756 | 7.732 | 5.250 | 7.580 | 5.048 | 7.544 |
| $R^2$ (%) | 55.93 | | 54.37 | | 54.21 | |

The *BOI* dummy variable has a positive sign in model A and a negative sign in model B. This is probably caused by the high correlation with *DISTBANG* and to a lesser extent with *DISTRAIL*. The coefficient is, however, in both cases not significant. The fact that the *BOI* variable is not significant is no surprise if one realizes that the BoI scheme was introduced in 1993, rather near the end of the period of analysis considered (1969-1995). A regression model with factories established from 1993 onward should give more insight on the effect of BoI policy.

We now turn to the accessibility variables. *DISTROAD* has a significant coefficient in all three models. This clearly confirms the theory, which states that accessibility plays an important part in location decisions. Since the variable is defined as the distance to main roads, causality is less of a problem here. The main road network existed before factories located in the area. Upgrading of roads, however, could be the result of factories locating at a certain place. For this type of infrastructure we do not find that accessibility has an adverse effect, a possibility mentioned in Section 2.

It is remarkable that the *DISTRAIL* variable has a significant positive sign in model A, meaning that companies prefer to locate away from railroads. This can be the result of the strong correlation with *DISTBANG*. In other specifications without *DISTBANG*, however, *DISTRAIL* keeps a positive sign.

A problem with the data used is that although they relate to the physical presence of infrastructure in terms of accessibility, data on frequency, reliability, quality of multimodal terminals, etc., are not included. As mentioned in Sections 2.4 and 3.2, such elements are important for the real impacts of infrastructure. Hence our operationalization implies that the services provided by using the infrastructure are measured in a rather limited way; this obviously hampers the analysis of infrastructure impacts.

*DISTBANG* is a significant variable in models B and C when *DISTRAIL* is deleted from the model. In such cases, however, it has a positive sign, which is contrary to expectation. One usually expects higher factory densities when one approaches the capital; population density, though, is already taken into account. It is interesting to note that the sign for *DISTBANG* in specifications B and C is different from that in the correlation matrix (Table 2). According to the correlation matrix, zones further away from Bangkok have lower factory densities. Our multivariate regression analysis reveals that this phenomenon is not so much due to a distance effect per se, but to less favorable scores for the other explanatory variables in zones further away from Bangkok.

As indicated in Section 2.4, anticipation of the completion of infrastructure projects may be an important phenomenon. A large part of this anticipation has been included because in this section we analyze actual location behavior and infrastructure improvements during some 25 years. This allows for a long period of adjustment and anticipation. It should be mentioned, however, that a certain part of the more recent locational patterns may essentially be anticipation of improvements of infrastructure that are not included as explanatory variables. As indicated in Section 2.4, much depends on the perceived certainty of future infrastructure projects. In the present paper we did not include possible future projects. Further research on the issue of anticipation would probably imply the use of other types of data (e.g., direct surveys of entrepreneurs about their location motives and their perceptions of future infrastructure projects).

### 4.2 Analysis of Industrial Location at Tambon Level

Table 4 shows the correlation coefficients of the model as formulated in formula (2) at the tambon level (with 905 tambon zones as opposed to 100 amphoe regions). Again a high correlation can be found between *DISTRAIL* and *DISTBANG*, and between *BOI* and *DISTBANG*. Most correlation coefficients are lower than those at amphoe level in Table 2. The correlation coefficients with *POPDENS* are especially much lower.

The results of the regressions are as expected. In Table 5 it can be seen that the $R^2$ decreases considerably, from about 55% to 8%. This is usually the case when the analysis is carried out at a more disaggregated level; the peaks and dips become more important and have a negative effect on the determination coefficient. The distance to a main road is again significant in all three regressions. The distance to a port is also significant in all three regressions, which was not the case in the first formulation of the model. The *DISTBANG* variable has in all cases the expected sign, and is even significant in model C. The *BOI* variable has in both cases a negative sign, but is not significant. The population density and the constant are also three times significant.

Another, related, explanation for the strong decrease of the determination coefficient for the regression at tambon level compared to that at amphoe level lies in the problem of spatial spillovers. The areas at tambon level are too small to hold more than one type of activity; the people who work at an industrial estate live in the adjacent tambon. Factories are not next to a road, but in a tambon somewhat further, accessible by a small entry road.

### 4.3 Sectoral Differences in Location Patterns

For an analysis of the location pattern of the different sectors, the total database has been divided into four sub-sectors. The factories have been grouped into the following four sectors:

*RESBASED*: Resource-based industries
*AGROBUS*: Agribusiness
*HEAVYIND*: Heavy industry
*LIGHTIND*: Light industry

The regression is executed again at amphoe level with 100 observations. Table 6 shows that some differences between the sectors exist. The correlations of *DISTPORT*, *DISTBANG* and *POPDENS*, especially, vary among the sectors. In particular, the correlation between *AGROBUS* and *DISTBANG*, and between *HEAVYIND* and *POPDENS* is rather low.

**Table 4. Correlation Coefficients for a Regression at Tambon Level**

| | *FACTDENS* | *DISTROAD* | *DISTRAIL* | *DISTPORT* | *DISTBANG* | *BOI* | *POPDENS* |
|---|---|---|---|---|---|---|---|
| *FACTDENS* | 1.000 | | | | | | |
| *DISTROAD* | -0.220 | 1.000 | | | | | |
| *DISTRAIL* | -0.091 | 0.298 | 1.000 | | | | |
| *DISTPORT* | -0.174 | 0.172 | 0.056 | 1.000 | | | |
| *DISTBANG* | -0.141 | 0.164 | 0.742 | 0.280 | 1.000 | | |
| *BOI* | -0.109 | 0.056 | 0.422 | 0.224 | 0.775 | 1.000 | |
| *POPDENS* | 0.148 | -0.134 | -0.049 | -0.096 | -0.087 | -0.070 | 1.000 |

**Table 5. Results of the Regression at Tambon Level (n=905)**
Note: a coefficient is in bold if significant at the 0.05% level following T-distribution.

| | A | | B | | C | |
|---|---|---|---|---|---|---|
| | coefficient | st. error | coefficient | st. error | coefficient | st. error |
| *DISTROAD* | **-1.972** | 0.381 | **-1.908** | 0.358 | **-1.884** | 0.356 |
| *DISTRAIL* | 0.057 | 0.115 | | | | |
| *DISTPORT* | **-0.116** | 0.043 | **-0.127** | 0.038 | **-0.127** | 0.038 |
| *DISTBANG* | -0.094 | 0.096 | -0.058 | 0.060 | **-0.083** | 0.039 |
| *BOI* | -2.401 | 7.214 | -3.757 | 6.679 | | |
| *POPDENS* | **0.010** | 0.003 | **0.010** | 0.003 | **0.010** | 0.003 |
| Constant | **61.400** | 6.172 | **60.825** | 6.061 | **61.597** | 5.902 |
| $R^2$ (%) | 8.45 | | 8.42 | | 8.39 | |

Table 7 reveals that many differences between the sectors indeed exist. The distance to a main road is a significant location factor for all sectors, except for heavy industry. For this sector, transport cost should be important; road transport, however, is probably not the preferred mode. Heavy industry also has the lowest determination coefficient, and only the distance to a port and the population density are significant.

Distance to a port is significant for agribusiness and heavy industry, whose products usually have a low value per weight-unit, in which case water transport is the cheapest mode. For resource-based industries, which also produce relatively heavy goods, a location close to the source of inputs is probably more important than one near a port.

The distance to Bangkok has for three sectors a positive sign. For agribusiness and resource-based industries this can be explained: agriculture usually takes place outside cities; and both sectors locate close to the source of their inputs. The impact of *RESBASED* and *AGROBUS* is probably the explanation for the unexpected negative sign for *DISTBANG* in the model above. For all industries, location in areas with high population densities is important. The availability of labor and proximity to a market, along with other agglomeration advantages, is a significant location determinant.

**Table 6. Correlation Coefficients for the Different Sub-sectors at Amphoe Level**

| | *RESBASED* | *AGROBUS* | *HEAVYIND* | *LIGHTIND* |
|---|---|---|---|---|
| *DISTROAD* | -0.365 | -0.364 | -0.264 | -0.319 |
| *DISTPORT* | -0.188 | -0.279 | -0.340 | -0.222 |
| *DISTBANG* | -0.213 | -0.120 | -0.308 | -0.204 |
| *POPDENS* | 0.723 | 0.646 | 0.388 | 0.643 |

**Table 7. Results of the Regression with a Division by Sectors at Amphoe Level (n=100)**
Note: a coefficient is in bold if significant at the 0.05% level following T-distribution.

| | A (*RESBASED*) | | B (*AGROBUS*) | | C (*HEAVYIND*) | | D (*LIGHTIND*) | |
|---|---|---|---|---|---|---|---|---|
| | coeff. | st. error | coeff. | st. error | coeff. | st. error | coeff. | st. error |
| *DISTROAD* | **-0.202** | 0.078 | **-0.216** | 0.089 | -0.051 | 0.054 | **-0.311** | 0.177 |
| *DISTPORT* | -0.003 | 0.009 | **-0.021** | 0.010 | **-0.014** | 0.006 | -0.021 | 0.020 |
| *DISTBANG* | **0.016** | 0.009 | **0.031** | 0.010 | -0.006 | 0.006 | 0.027 | 0.021 |
| *POPDENS* | **0.032** | 0.003 | **0.032** | 0.004 | **0.006** | 0.002 | **0.057** | 0.008 |
| Constant | -0.644 | 1.726 | 2.481 | 1.950 | **3.510** | 1.194 | 0.077 | 3.928 |
| $R^2$ (%) | 56.58 | | 51.20 | | 23.91 | | 44.78 | |

## 4.4 Location in Time

The last estimations concern the introduction of time. This is rather difficult because of lack of data. We distinguish three different periods, and for each calculate distances in a GIS with a historic main road network. The historic population density is also not available, so the actual population density is used for all estimations. In the first periods the ports had not been constructed yet. The periods are:

*FDY6986*: Factory density per amphoe for factories established between 1969 and 1986 (which corresponds with the pre-boom years of the economy). The total number of factories established in this period is 2763;

*FDY8790*: Factory density per amphoe for factories established between 1987 and 1990 (which corresponds with the boom years). The total number of factories established in this period is 1037;

*FDY9195*: Factory density per amphoe for factories established between 1991 and 1995 (corresponding with the post-boom years). The total number of factories established in this period is 2944.

From the results in Table 8 we see that while the location preferences were different in the first period, the last two periods have rather similar outcomes. In the first period, location away from Bangkok is significant. This is the result of the relative importance of agro-industries, which locate close to their resources. Location close to a main road was also not so important in the first period, although the road network was less developed in that period. This is also probably

**Table 8. Results of the Regression with Different Periods**
Note: a coefficient is in bold if significant at the 0.05% level following T-distribution.

| | A (*FDY6986*) | | B (*FDY8790*) | | C (*FDY9195*) | |
|---|---|---|---|---|---|---|
| | coefficient | st. error | coefficient | st. error | coefficient | st. error |
| *DSTRD75* | -0.129 | 0.092 | | | | |
| *DSTRD88* | | | **-0.094** | 0.055 | | |
| *DSTRD95* | | | | | **-0.427** | 0.179 |
| *DISTPORT* | | | -0.009 | 0.007 | -0.034 | 0.022 |
| *DISTBANG* | **0.046** | 0.018 | 0.011 | 0.007 | 0.011 | 0.022 |
| *POPDENS* | **0.064** | 0.005 | **0.019** | 0.003 | **0.044** | 0.009 |
| Constant | -6.657 | 2.225 | 0.731 | 1.415 | **8.639** | 4.429 |
| $R^2$ (%) | 67.66 | | 41.82 | | 36.73 | |

the result of the nature of the industries; in the later periods more non-agricultural industries established in the ESB. In the first period the location could be explained rather well by the variables in the model.

The *BOI* variable has not been included in the regression models because of the strong correlation with *DISTBANG*. Performing several estimations with combinations of *BOI*, *DISTBANG* and the factory densities in the different periods showed that *BOI* did not have the expected sign and was not significant. The correlation (with the wrong sign) between the factory densities in the different periods and *BOI* even increased in the last period, when the zoning system of the BoI came into effect. However, several observations indicate that the BoI zoning system is effective. A GIS analysis showed a high number of BoI applications in Prachinburi, the zone III nearest to Bangkok. Several industrial estates have located just outside zone II, in zone III. In one case an industrial estate built a 10 km private road just to be in zone III.[1] The fact that BoI applications have been made close to the zone borders, and not further inside zone III, could also blur the results of the statistical analysis.

[1] We thank a referee for this information.

For the last period, covering 1991-1995, the aforementioned problem of unavailability of lagged population data is not as serious. Note that also in this period we observe a significant orientation in firm location behavior toward high density areas. Thus the regional development policies aimed at reducing the polarization in the national economy, reflected by the dominant position of Bangkok, lead to a (much milder) process of polarization within the regions toward the medium sized cities located there. As indicated by Johnson (1970) and Rondinelli (1985), this is a welcome result for the development of rural regions.

## 5. Conclusions

Our analysis indicates that the local labor force is a main determinant of location patterns of the manufacturing sector in the Eastern Seaboard. This reflects both the importance of urbanization economies and the availability of (skilled) labor; lack of skilled labor appears to be a limiting factor in Thai regional economic development. It is not possible, however, to reveal the precise mechanism of manufacturing sector location and labor interaction, as data on the past development of population or labor force are not available at a detailed spatial level. The issue of causality is a point that deserves ample attention in infrastructure research.

The impact of infrastructure is relatively modest. Distance to main road and ports are significant; their contribution to the explanation, however, is rather small. Zones further away from Bangkok tend to be slightly more successful in attracting manufacturing firms. The background of this phenomenon is that most are resource based or agribusiness.

Finally, our analysis of manufacturing location data did not reveal a significant impact of the financial investment incentives of the Thai government. However, it may be too early for a definitive conclusion on this, since most of the locations considered were established in the period before the incentive scheme was introduced. There is some recent evidence—which could not be included in the statistical analysis—that the investment incentive schemes are indeed effective.

As indicated in Section 2, a positive relationship between transport infrastructure and industrial location cannot be taken for granted; a negative relationship may also occur due to substitution and competition. In the case of Thailand we did not find this result: roads and ports tend to have a positive, though limited effect.

*The authors thank two anonymous referees for very helpful comments.*

*Final version received January 1999.*

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